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Business Information Visualization for Decision-Making Support
-- A Research Strategy

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Introduction

In most management domains, problem-solving is overwhelming because of the large amount of complicated data, multiple complex relationships among data, and the negotiability of the constraints. Although computers become more and more available, the primary challenge of the computing society in the current and coming decades is not the computational power. It is the collected or generated data, especially their presentations to users in a comprehensible form, that affect and limit the basic capabilities of computing. It is extremely necessary to improve the communication between users and computers, to transform the vast computing-related data into some representations that help humans to understand the data. Humans are visual creatures. Most of what we learn comes through our sight. An effective solution to the challenge is to shift some of the user's cognitive load to human perceptual systems by using computer-generated, domain-specific visualizations.

Based on the previous research results in the development and the evaluation of a visualization-based decision support system for manufacturing production planners [Zhang 95], this research paper focuses on developing a research strategy for building visualizations of non-geometric data that are massive in both size and dimensionality to help decision makers to achieve data comprehension and eventually to improve problem-solving performance. The practice of business information visualization needs guidelines from theoretical perspectives, as well as practical perspectives. As business information visualization is an area where few theoretical and practical results have been obtained, we construct the visualization theory by expanding related work in other fields. We will then apply the visualization model to concrete business domains to verify the effectiveness of the model. We hope that a new discipline for business information visualization will be established and it will have its own theoretical foundation and methodology. As the visualization of large data sets is a problem of concern in many management domains, this research has both theoretical and practical contributions.

Literature Review and Research Objectives
Limitations of general statistical graphs are two-fold: First, the data to be graphed must have controllable size or dimensions. Secondly, due to the powerful computing capability, sophisticated underlying functionality, and complexity of data in different domains, general purpose representations are not easy to apply to a specific domain.

People have tried to discover ways to graphically represent huge data sets. Shneiderman et al. [92] developed TreeMaps to represent computer hard disk usage, where huge data sets are involved and compressed. Perlman [83] used a "punctuation graph" to represent a technical document to allow the writer to detect potentially overly complex sentences, as well as recognize familiar patterns. The limitation of these research results is that the relationships among data sets are geometric in structure, such as hierarchies, linear, or networks. In many business domains, however, the relationships among data are very complicated. There might be no geometric structure that is implied by the data themselves. In other words, there is no obvious physical model that can be used to represent the data that humans can understand objectively. This nature of data causes a challenge for graphically representing data: a concrete, comprehensible geometric structure has to be created for representing the data. We call this type of data non-geometric data or non-spatial data.

We noticed that little research and few applications for decision making support systems emphasize this issue or even recognize this issue of graphically representing large amounts of non-geometric data. For example, Executive Information Systems handle limited data size and relationships. The executives complain that they have too many data and most of the data are irrelevant.

Scientific visualization technology has provided many applications for spatial data visualizations [McCormick 87, DeFanti 89]. However, few, if any, research or practical results have been succeeded in visualizing the non-spatial data that can be easily found in business domains.

In summary, no research results have been found that use computers to graphically represent high-dimensional, large-sized, non-geometric-based management data for decision-making support. This is our position and our challenge, hence our contribution to the field of Information Systems research.

Our long-term research objectives are two-fold: First, to provide practical guidelines for applying visualization techniques to the business decision-making area; Secondly, to develop a research strategy for domain specific business information visualization to aid human decision-making processes. We have achieved positive results on our first goal. Based on the previous results, we are constructing the theatrical foundation for business information visualization. Eventually we hope to build this new discipline of visualizing business information for decision-making support.

A General Model
The decision problem in this research has the following characteristics: there are large amounts of non-spatial data with complicated relationships; the decision-making environment is flexible because many things are negotiable; numerical computations are very necessary; the final decisions are made by human beings, not by computers; and most decisions have to be made under time pressure. Examples of these decision problems can be found in production planning, inventory control, and stock market domains.

The visualization model itself is domain-independent. It indicates the procedure for business information visualization by starting from a business domain, having step-by-step processes that are guided by the related theories, and having results for each process. The final output of the visualization model is a set of displayable visual representations that support the entire human problem-solving process in a specific business domain. There are possible iterations among different processes, just as in any human's problem-solving process, modeled by Simon et al. [Newell & Simon 72]. The five processes are as following.

**Domain Problem Space Analysis**

This is about what types of problems exist in a specific business domain, how they should be solved and evaluated. This process is guided by the general problem-solving model developed by Simon et al. We believe that the ultimate goal of visualizing management data is for supporting human's problem-solving or decision-making processes. Thus the user interface should support the human activities and improve the entire problem-solving performance. The outcome of this process is the domain problem space hierarchy with evaluation criteria for alternatives.

**Domain Data and Knowledge Collection**

This process is a detailed, further analysis of domain tasks and is guided by information analysis theory [Bertin 63] and knowledge base construction rules in the AI discipline. It focuses on the problem space, analyzes each node in the problem space, identifies each data item and information component (variable), the characteristics of the information components, and the relationships among information components. The final collection of data is stored in a conceptual database. The relationships among variables and rules that apply to problem-solving activities are described as a set of knowledge and form a conceptual knowledge base.

**Pattern Discovery and Data Aggregation**

This is a special process for dealing with the massiveness in both size and dimensionality of the data. Only a limited number of information components with limited elements can be displayed because of the limited display space. However, in the business world, it is very typical that the decision-making process involves multiple information components, some of them have almost unlimited elements. There are two major concerns: First, among all the existing multiple relationships in the data, how do we find the subsets
(patterns) that are most interesting or most important to the decision makers and that should be displayed? Secondly, how should we compress an information component with unlimited elements into effective indicators that are displayable in size? Our ultimate goal is to develop a mechanism of visualizing different types of patterns and indicators. Knowledge Discovery in Databases (KDD) is a research frontier for nontrivial extraction of implicit, previously unknown, and potentially useful information from large amounts of data [Wu 94, Piatetsky-Shapiro 94, Matheus et al 93]. Some of the KDD techniques can be used for finding the patterns and indicators.

**Image Construction**

Due to the non-spatial nature of most business data, concrete visual representations have to be created. The major concern for graphics construction is the efficiency of the final visual representations for human vision. This process involves creation of images with geometry and has to do with human visual perception characteristics [Caeli 81], and cognitive processes of visual information processing [Kaufmann 79]. Special rules should be followed in order to create efficient images with legibility [Bertin 63]. The outcome of this process is a set of abstract objects with geometric structures that may be in 2D, 3D, or MD spaces.

**Rendering Images as Displayable Visual Representations**

This process makes sure that multiple dimensions can be represented properly on a 2D surface. It includes projection from higher dimensions to 2D, rotation, scaling, clipping, and perspective mapping. Existing scientific visualization techniques [Nielson et al. 90] are very helpful.

**Conclusions and Future Research**

The theoretical contribution of this research is that we proposed a general visualization model for building domain-specific visualization-based user interfaces for problem-solving support in any managerial domain. The techniques and theories in other related disciplines are expanded and modified to provide the foundation for this brand new discipline.

Our next research step is two-fold: First, to refine the general model by providing operational steps for practice; Secondly, to finalize the general visualization model by applying it to another business domain, such as the finance domain.

**References**


